Section 13

Hyperion Ground Test and On-Orbit Performance

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Hyperion Ground Test & On-Orbit Validation

- ***Message***
  - ***Extensive pre-flight characterization***
  - ***On-orbit assessment confirmed pre-flight characterization***
- ***System performance assessment strategy***
- ***Present pre-flight and on-orbit measurement techniques***
  - ***Absolute radiometric calibration***
  - ***Spectral calibration***
  - ***Image quality characterization***
- ***Compare on-orbit status with pre-flight and requirements***

Strategy

- **Pre-Flight:**
  - *Establish fundamental characteristics of the instrument and assess requirement compliance*
  - *Establish instrument performance through the build, environmental test and spacecraft integration phases*
  - *Provide solid foundation for on-orbit comparison*
- **On-orbit:**
  - *Determine on-orbit performance and compare with pre-flight performance*
  - *Define data collects that can be used to assess identified performance parameters*
  - *Acquire and analyze data collections; and assess accuracy of technique*
  - *Compare on-orbit results with pre-flight*
- **Review and document results**

Absolute Radiometric Calibration

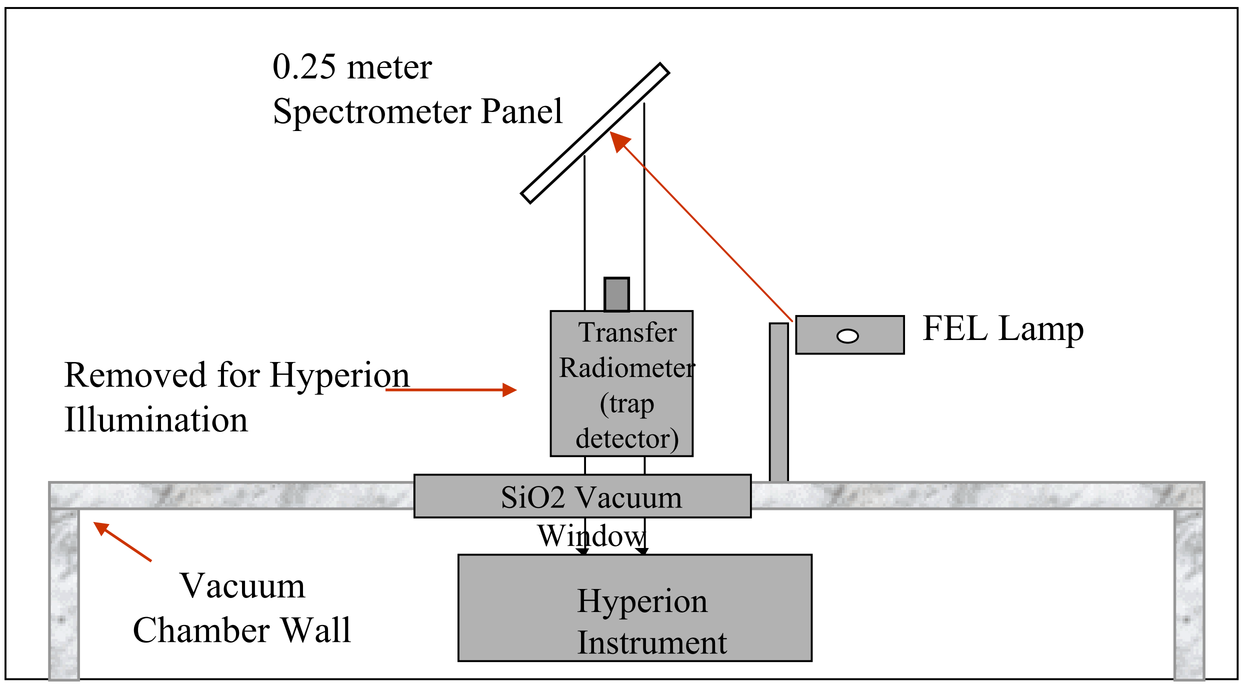
Absolute Radiometric Calibration

- ***Pre-flight Absolute Radiometry established, primary standard tied to fundamental physics and cross checked***
  - *Calibration Panel Assembly used in TRW test bed facilities*
  - *Linearity, Repeatability, Temperature Sensitivity, Dark Removal*
  - *Artifact Removal, Saturation Threshold*

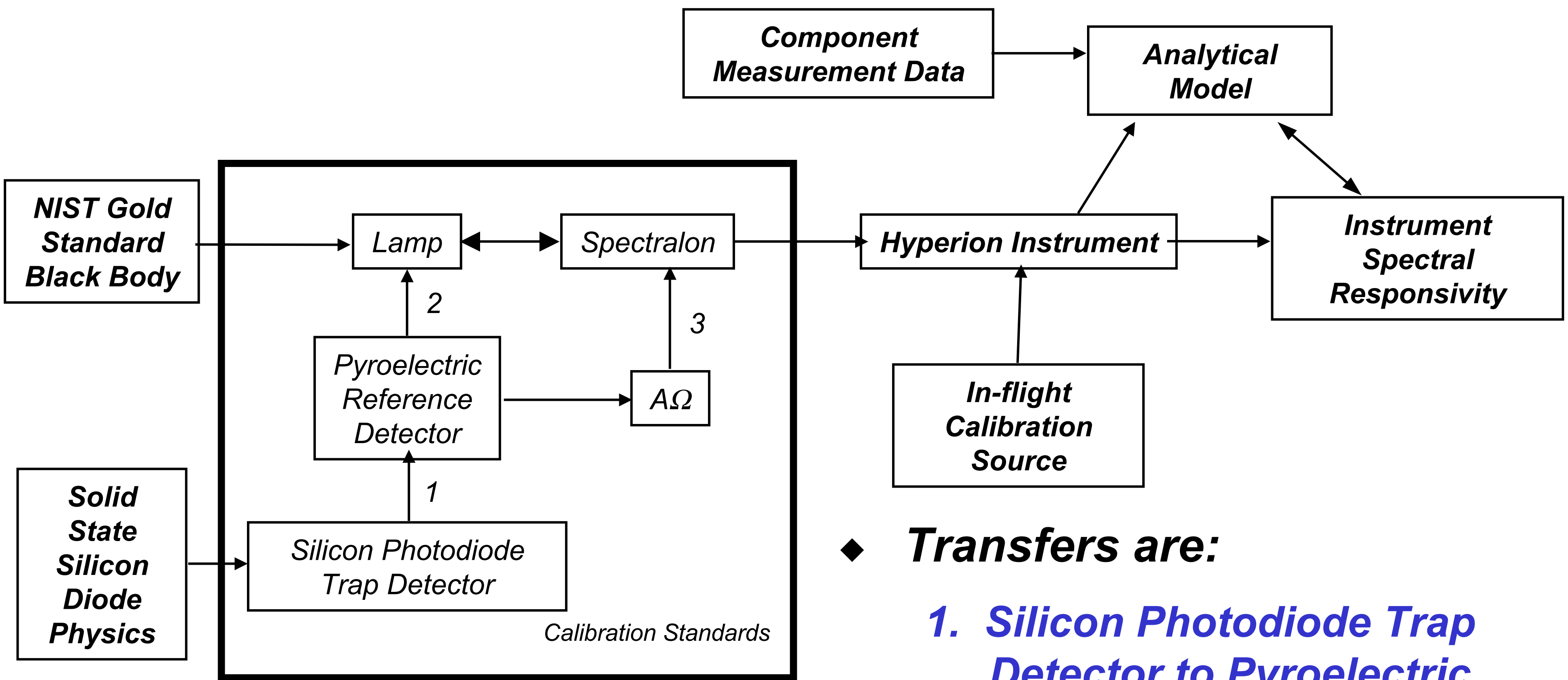
FEL Lamp tied to high-quantum efficiency Si trap detector primary standard and to NIST calibration

FEL Lamp illuminates the instrument

Hyperion tied to primary standard through the FEL Lamp



Absolute Radiometric Calibration Flowchart



- **Transfers are:**
  1. ***Silicon Photodiode Trap Detector to Pyroelectric Reference Detector (PRD) in Watts***
  2. ***PRD to Lamp in Irradiance***
  3. ***PRD/ AW to Spectralon plate in Radiance***

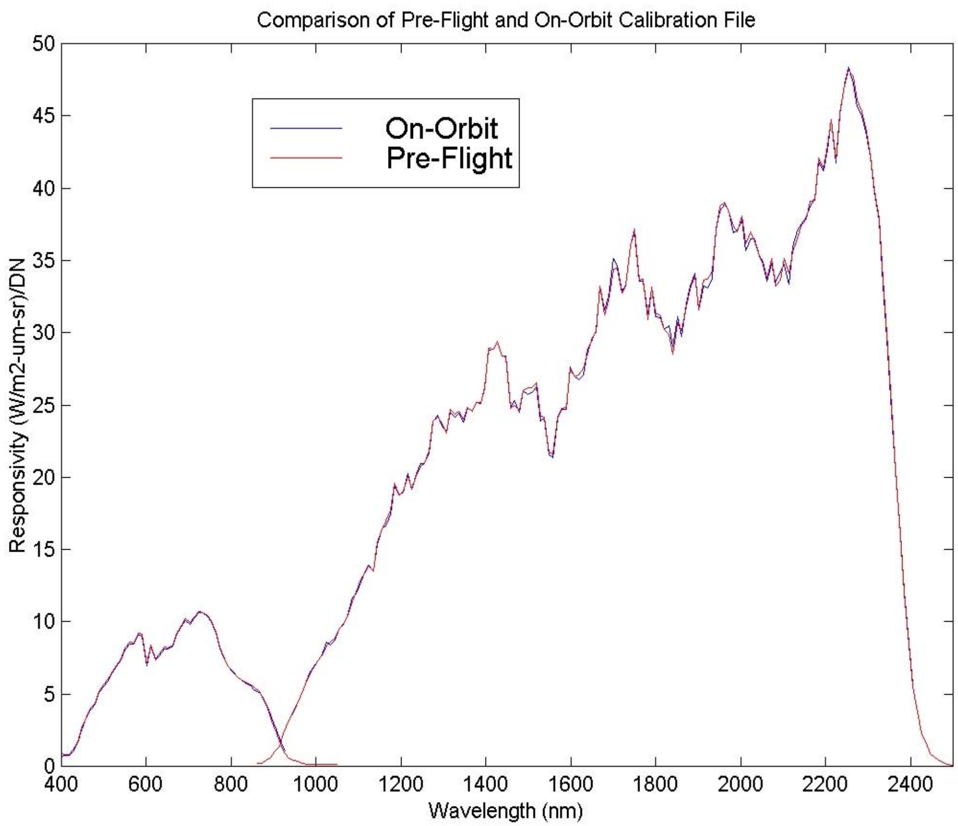
On-Orbit Radiometric Calibration

- ***Pre-flight Calibration transferred to On-Orbit Calibration***
- ***Solar Calibration***
  - *Absolute Comparison: VNIR within 2%, SWIR 5-8% low; SWIR has larger uncertainty due to solar model and BRDF model of cover surface*
  - *Used to correct for pixel-to-pixel corrections*
  - *Included in repeatability assessment 0.6% for VNIR, 1.6% for SWIR*
  - *Used to define noise level as a function of signal level to determined SNR*
- ***Lunar Calibration***
  - *Used to reveal otherwise undetectable artifacts and verify proper artifact correction*
  - *Absolute under review, preliminary results indicate agreement within 5% below 700 nm.*
- ***Vicarious Calibration and Cross Calibration***
  - *Lake Frome supported VNIR, missed coincident ground collect impacted SWIR comparison*
  - *Extensive Railroad Valley Comparison under way: Hyperion-ALI-AC-Landsat-7-Modis-Aster-Ground Truth*

Radiometric Error Budget

	VNIR	SWIR
Total Measurement Error	***2.95***	***3.39***
Absolute (Systematic) Error	***2.49***	***2.49***
– *Primary Standard*		
– *Cal Panel Assembly*		
– *Ground Calibration*		
– *Responsivity change on launch*		
Precision Error	***1.60***	***2.30***
– *Pixel-to-pixel variation*		
– *DCE-DCE Variation*		
– *Calibration drift*		
– *Residual Radiometer Artifacts*		
– *Dark Removal*		
– *Single Sample Noise*		

Pre-Flight Radiometric Performance Verified On-Orbit



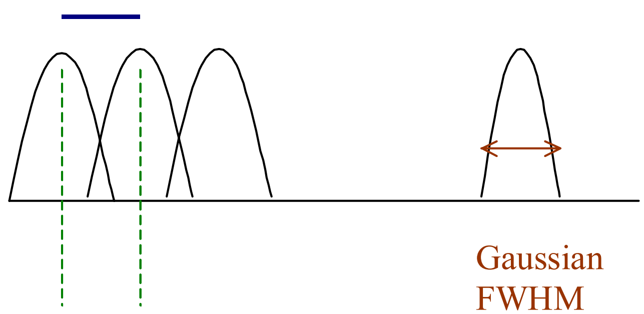
Signal-to-Noise Ratio

λ	Rqmnt	Pre-Flight	On-Orbit
550 nm	> 60	150	192
650 nm	> 60	140	140
700 nm	> 60	140	140
1025 nm	> 60	90	65
1225 nm	> 60	110	96
1575 nm	> 60	89	64
2125 nm	> 30	40	38

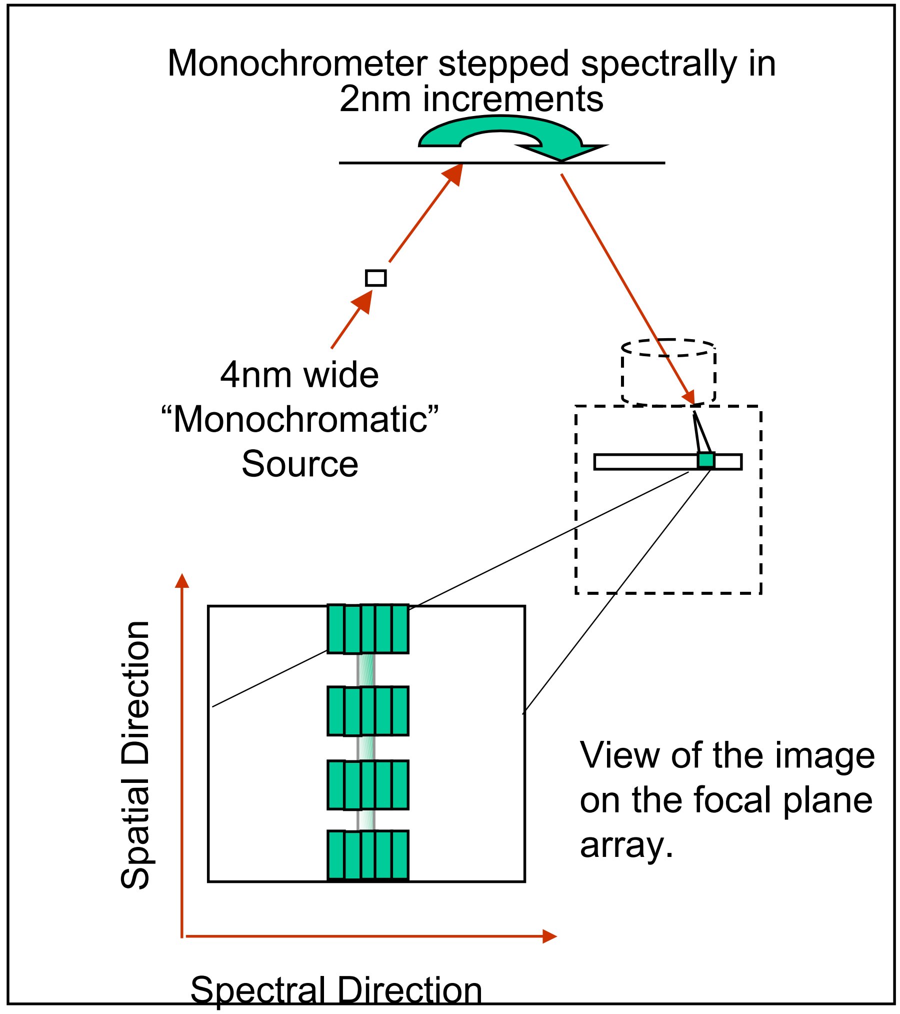
Spectral Calibration

Pre-Flight Spectral Calibration

- ***Spectral response modeled as a gaussian with a center wavelength and full width half max***



- ***TRW Test bed enabled creation of monochrometer profiles used to define center wavelength and bandwidth at discrete locations***



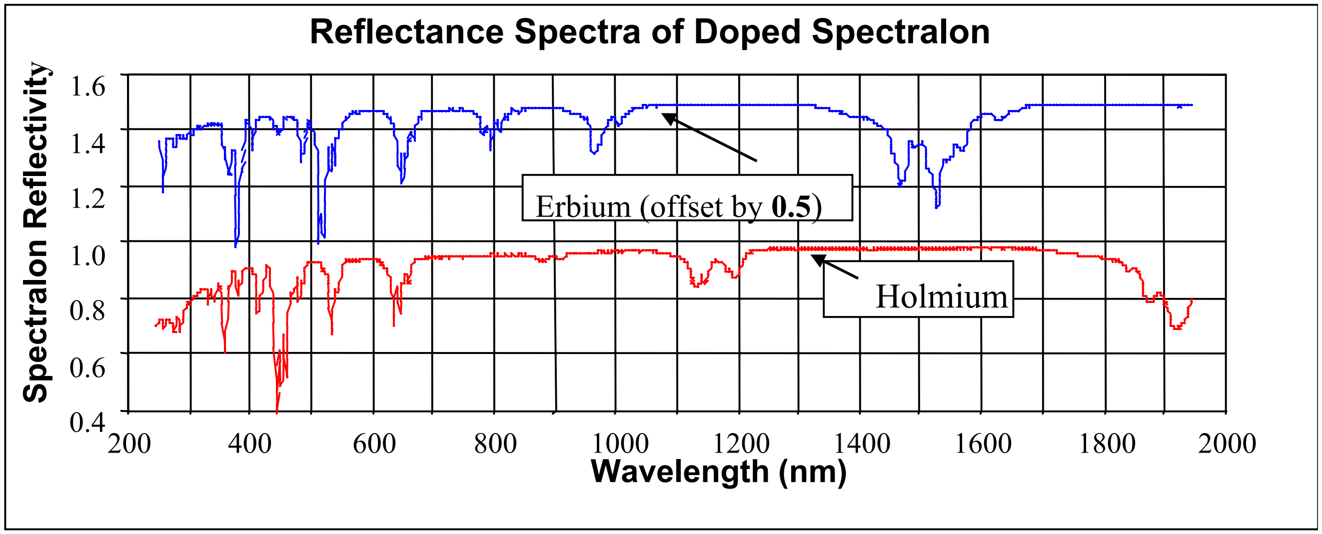
Pre-Flight Spectral Calibration

- ***Center wavelength and Bandwidth***
  - *Measured at discrete locations 20 VNIR locations, 25 SWIR locations.*
  - *Used to define the center wavelength and bandwidth for every VNIR and SWIR pixel, 256 field-of-view locations and 242 spectral bands.*
- ***Dispersion*** *(nm/pixel)*
  - *Spacing of spectral channels, Hyperion dispersion (~10nm/pixel) closely matches the bandwidth (10 nm)*
- ***Cross-track spectral difference***
  - *Maximum wavelength difference across field-of-view for a single spectral channel,*
  - *VNIR = 2.6-3.6 nm*
  - *SWIR = 0.40- 0.97 nm.*

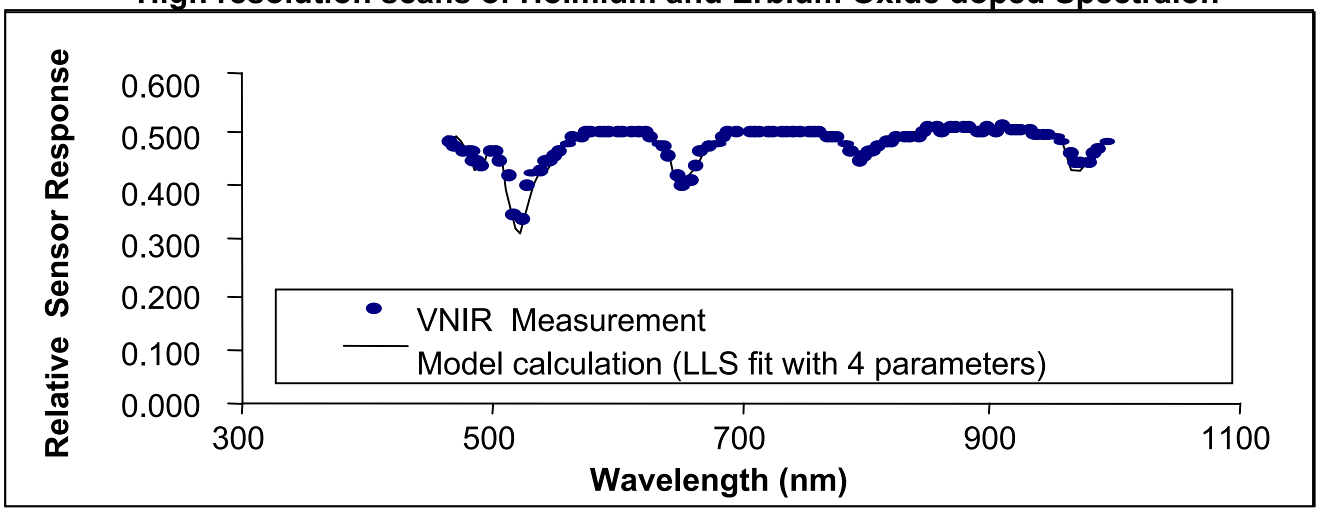
Pre-Flight Calibration Algorithm Development

Process:

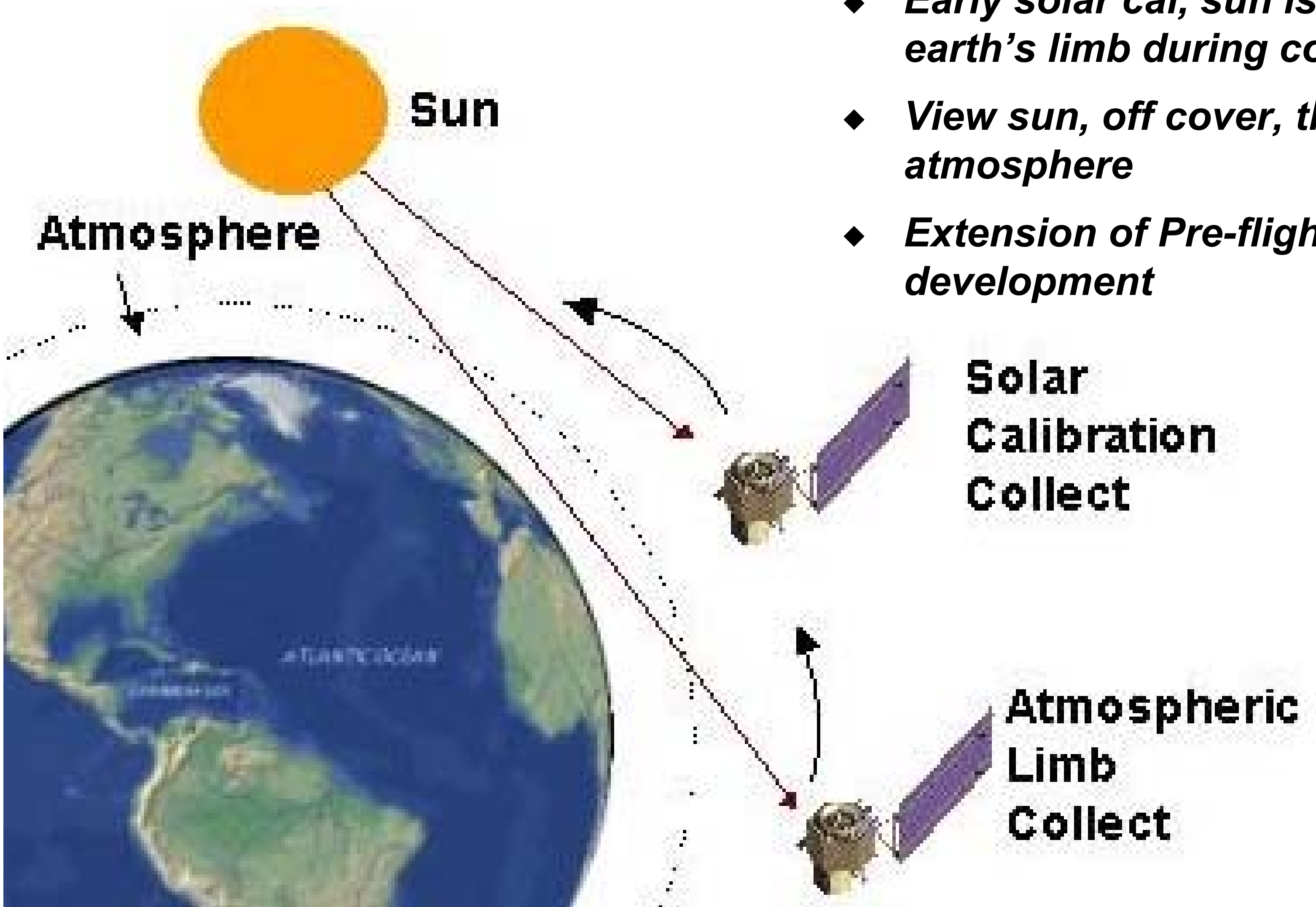
1. ***Image contains reference spectra uniform across the field of view. (pre-flight: doped spectralon)***
2. ***High resolution reference spectra convolved with sensor spectral response function***
3. ***Resulting reference spectra aligned with Hyperion measured spectra to determine spectral calibration.***



High resolution scans of Holmium and Erbium Oxide doped Spectralon



On-Orbit Spectral Calibration



- ***Early solar cal, sun is rising through earth's limb during collect.***
- ***View sun, off cover, through atmosphere***
- ***Extension of Pre-flight algorithm development***

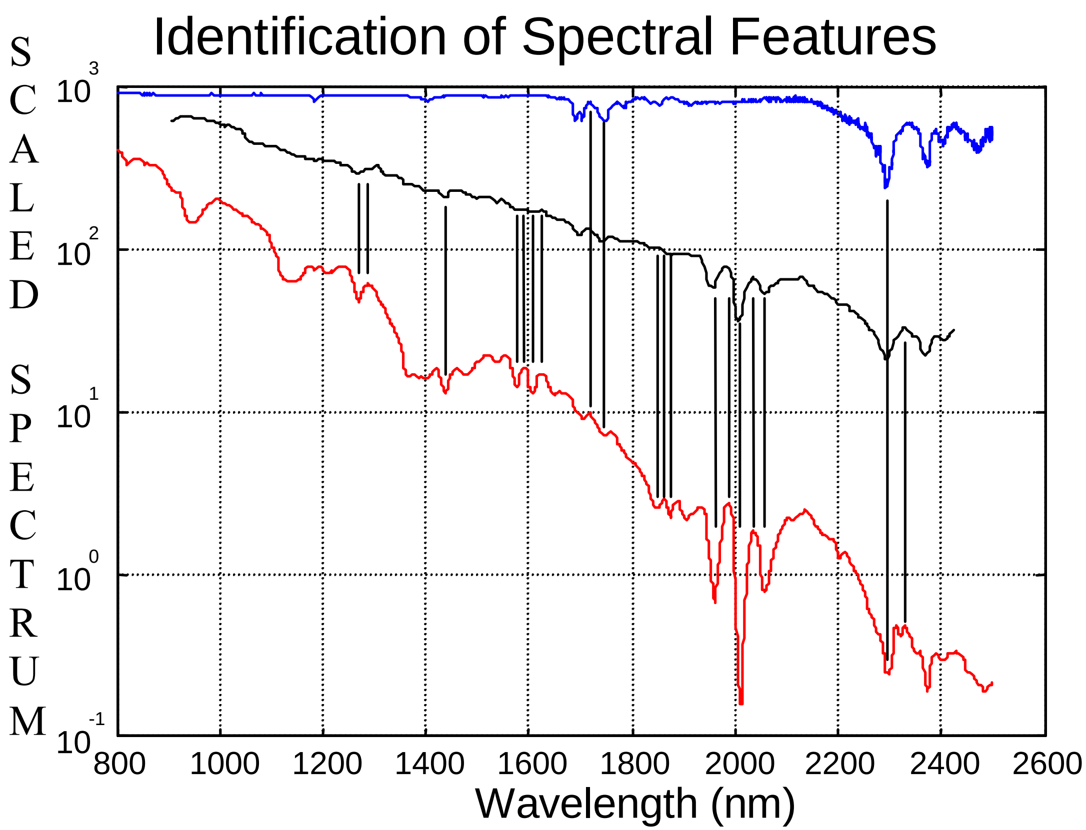
Spectral Calibration

SWIR

Cary 5 & FTS measured Diffuse Cover Reflectance – blue

Hyperion Spectra of Atmospheric Limb Collect – red

Atmospheric Reference Profile from Modtran 3 – black



VNIR

- ***Spectral calibration based on two lines: one solar line (520 nm) and an oxygen line (762.5nm)***
- ***Pre-flight calibration adjusted by an offset and rotation to match the solar and oxygen reference lines***
- ***No change in calibration recommended based on on-orbit data***

Released new spectral calibration file based on re-analysis of pre-flight data

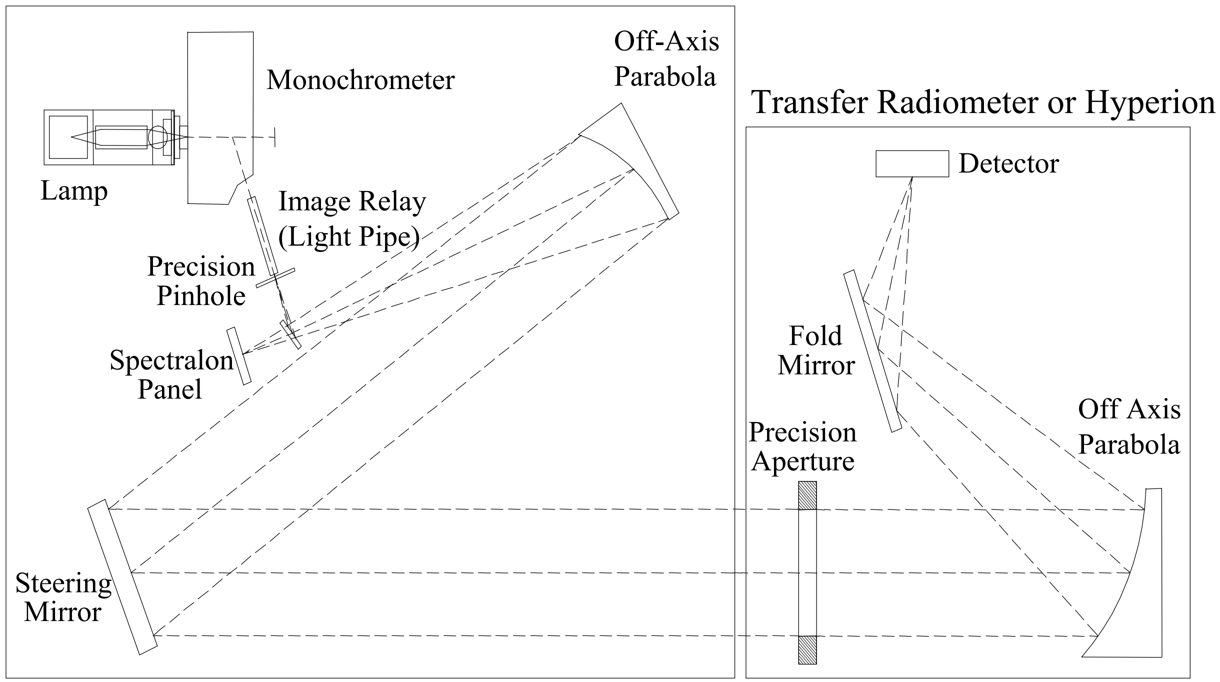
Pre-Flight Spectral Performance Verified On-Orbit

	Instrument Parameter	Requirement	Pre-Flight	On-Orbit
Number of Spectral Channels	VNIR & SWIR	220	comply	comply 200 selected for Level 1
Spectral Range		400-2500 nm	357-2576 nm Calibration $\pm$ 1 nm	357-2576 nm 436-2406 nm selected for Level 1 Analysis results $\pm$ 3 nm
Spectral Bandwidth	VNIR	10 +/- 0.1 nm	10.08–10.09	Not measured
	SWIR	10 +/- 0.1 nm	10.11-10.13	Not measured
Cross Track Spectral Error	VNIR	1.5	2.57-3.59 (waivered)	1.71-2.55
	SWIR	2.5	.17-.98	.40-.97

Image Quality

Hyperion Characterization

- ***Two modes of Operation:***
  - *1) Pinhole, slit and/or Knife Edge at end of light pipe put at focus of Off-axis Parabola (OAP)*
  - *2) End of light pipe is re-imaged onto Spectralon panel. Both are shown simultaneously in chart without re-imaging optics*
- ***Steering mirror is a two axis, fine pointing mirror (± 1-2 mrad) for sub-pixel scanning in spatial dimensions***



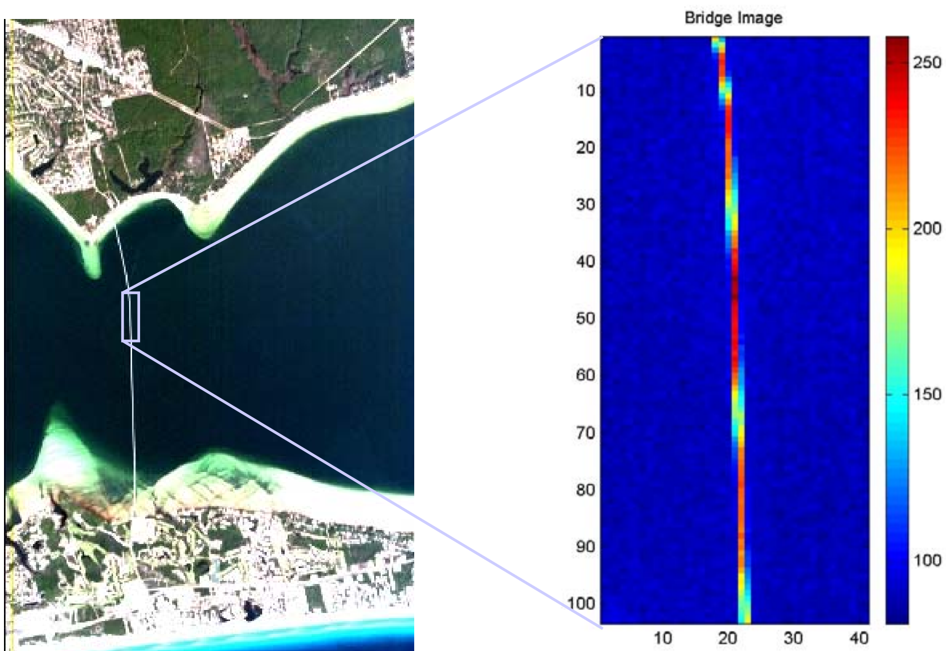
- ***Transfer radiometer is removable box for calibration of source***
- ***Radiometer uses chopped pyroelectric detector***
- ***Accurate AW is calculated from precision apertures and OAP focal length***

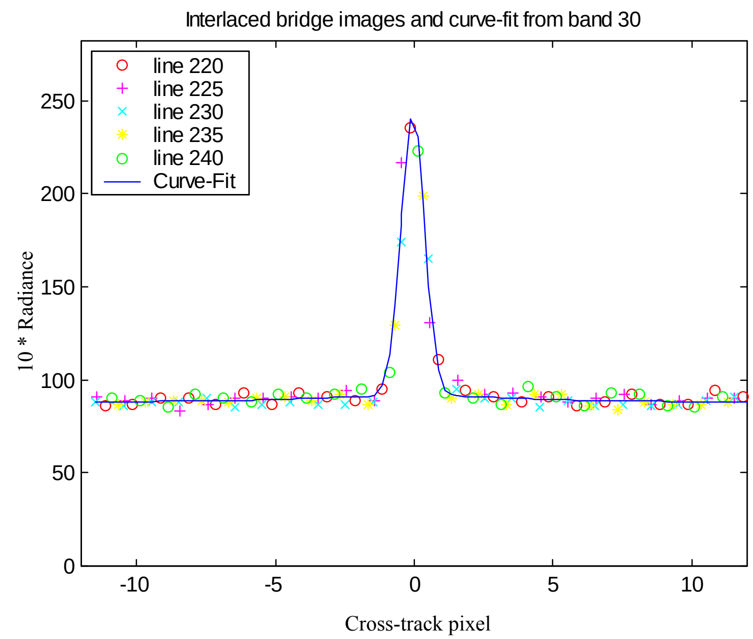
Image Quality

- ***Modulation Transfer Function***
  - *Pre-flight used knife edge and slit to measure Cross track direction, then Along-track was Cross-Track*2/pi*
  - *On-orbit used Ice Shelf & Lunar Limb (knife edge) and bridge (slit) to measure Cross-Track and Along-Track directly.*
- ***Co-registration of VNIR and SWIR***
  - *Pre-flight used test bed to project a slit with a broad spectrum at multiple locations*
  - *On-orbit used combination of edges (Lunar, Ross) and point sources (clouds, flares)*
  - *On-orbit best result obtained with vicarious calibration result of geo-locating the Hyperion data to the ground*
- ***Ground Sample Distance***
  - *Pre-flight measured IFOV using test bed*
  - *On-orbit triangulated marked features in well mapped scene*

MTF Example: Cross-Track Bridge

- ***Port Eglin, Dec 24, 2000. Bridge is the Mid-bay bridge near Destin, Florida.***
- ***Bridge width (13.02 m) acquired and utilized in the MTF processing.***
- ***Bridge angle small, every 5th line used to develop high resolution bridge image.***
- ***MTF result at Nyquist is between 0.39 to 0.42 while the pre-flight measurement was 0.42.***





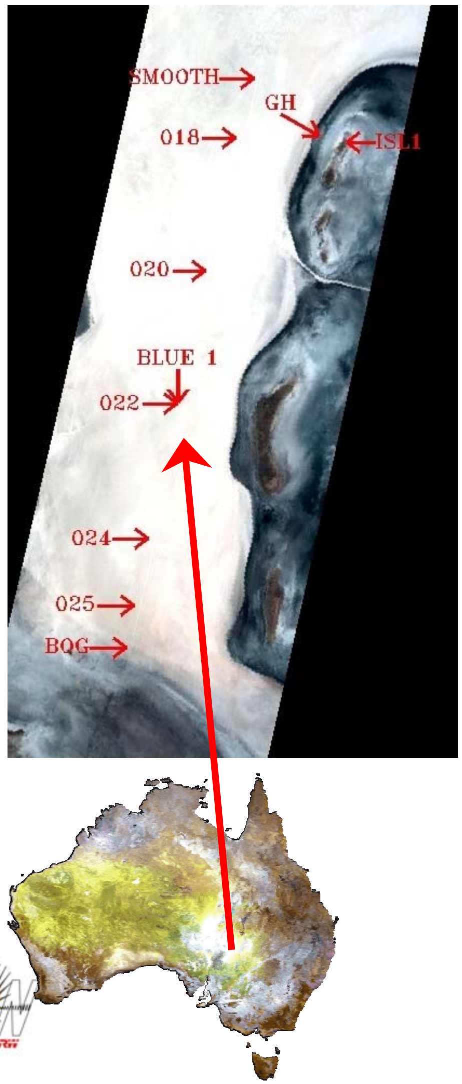
Pre-Flight Image Quality Performance Verified On-Orbit

	Instrument Parameter	Requirement	Pre-Flight	On-Orbit
GSD	Entire Range	30 m +/- 1 m	29.88	30.38
Swath Width	Entire Range	> 7.5 km	7.75 km	7.75 km
MTF (In-Track)	450 nm	> 0.2	.22-.29 meas. @ 500nm	.23-.27 meas. @ 500nm
	630 nm	> 0.2	.22-.27	.23-.27
	900 nm	> 0.15	.22-.24	.24-.28
	1250 nm	> 0.14	.27-.30	.20-.25
	1650 nm	> 0.15	.25-.27	.28
	2200 nm	> 0.15	.23-.28	Not avail
VNIR spatial Co-Registration	All	20% of Pixel	Waivered, 0.1-0.25	Consistent, 0.1-0.3
SWIR spatial Co-Registration	All	20% of Pixel	Waivered, 0.18-0.28	Consistent, 0.1-0.4

End-to-End Measurement

Desert Sites Used for Vicarious Calibration

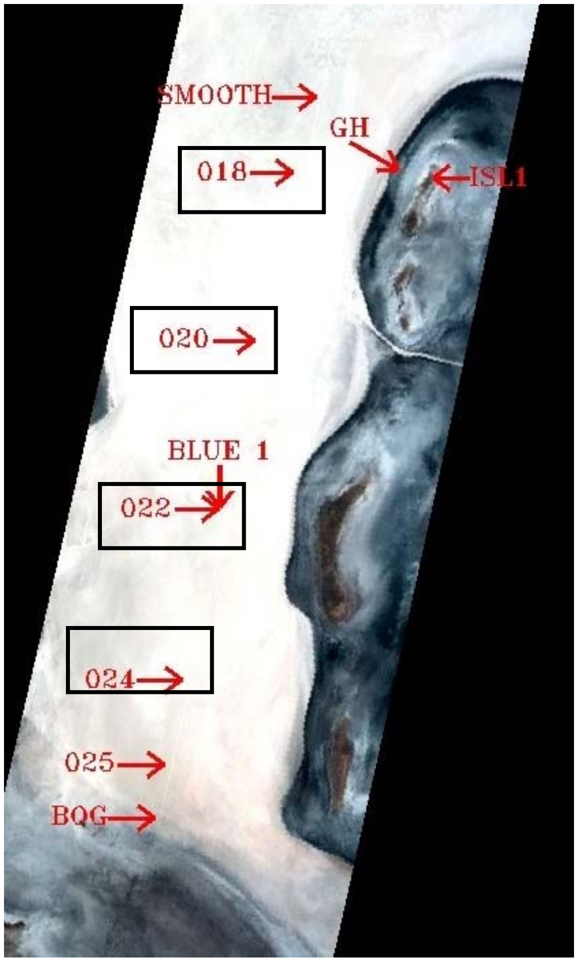
Lake Frome



RR Valley

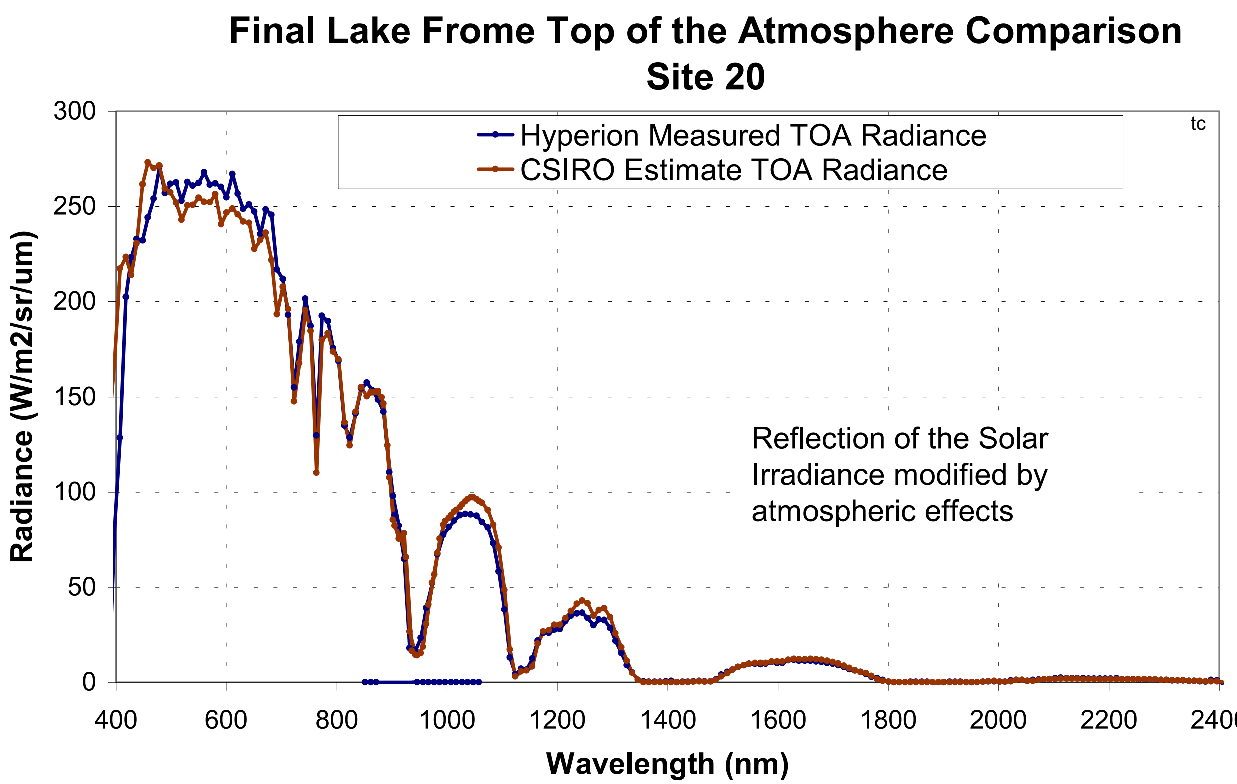
Arizaro/Barreal Blanco

Lake Frome Comparison Process



High resolution ground reflectance convolved with Hyperion Bandwidth and sampled at Hyperion center wavelength.

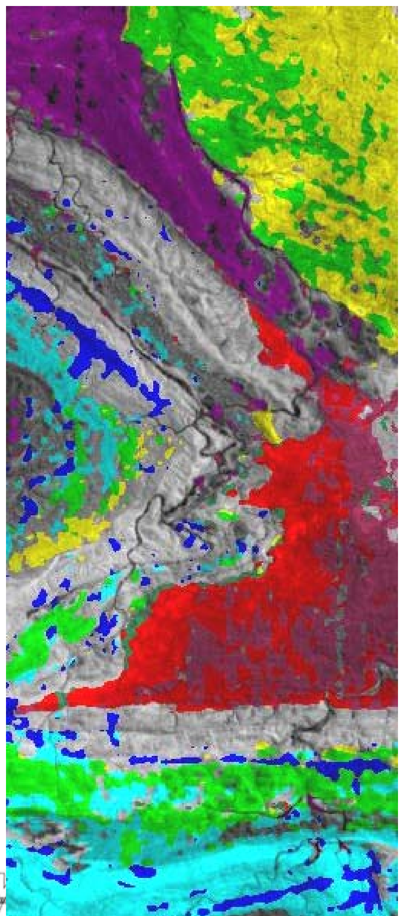
Modeling of atmosphere enabled transfer to top of the Atmosphere Comparison. Geo-location identified Hyperion pixel location.



Geology Maps *(Mt. Fitton)*

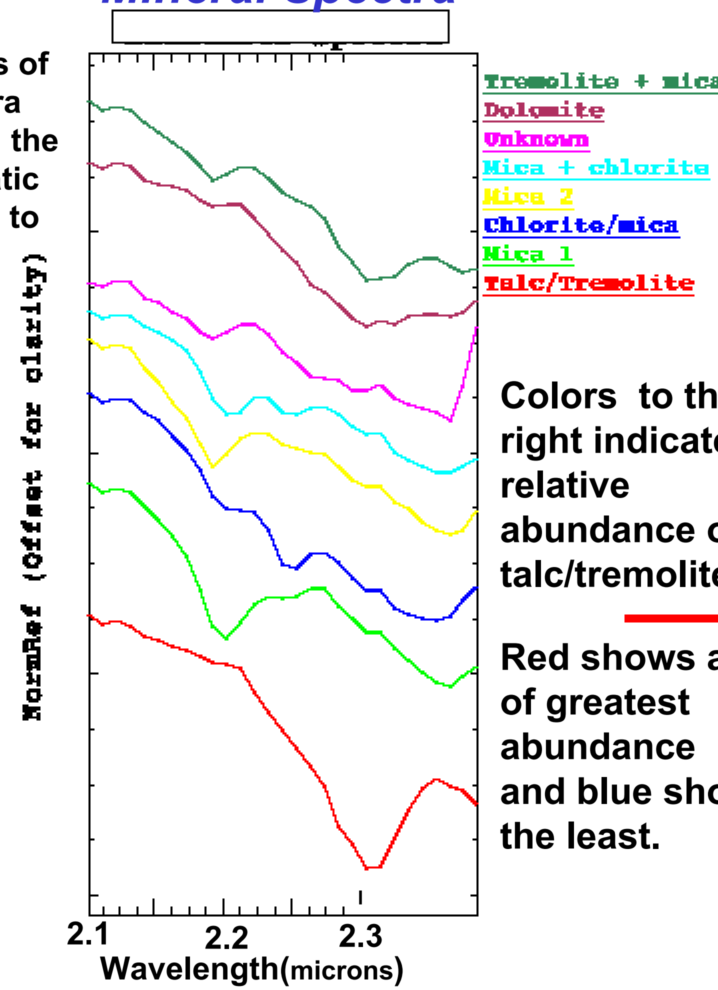
Automatic mineral mapping algorithm creates, in 30 seconds, a quick-look mineral map (left & centre). More precise detail is on right. *(Courtesy of CSIRO Australia)*

Mineral Map



Mineral Spectra

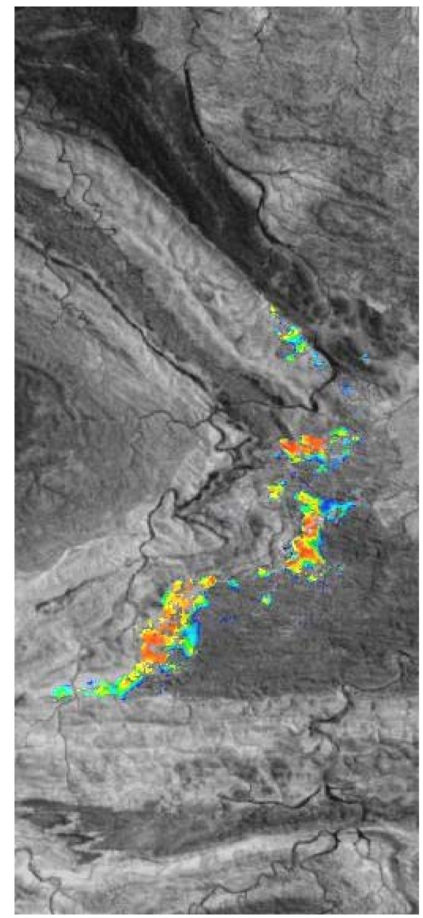
Colors of spectra match the thematic image to left.



Colors to the right indicate the relative abundance of talc/tremolite .

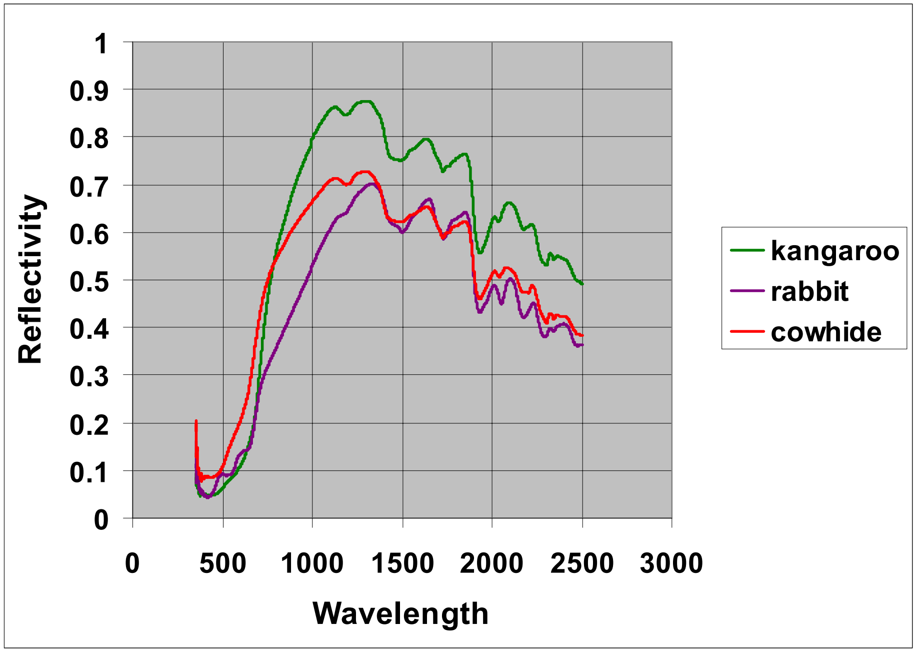
Red shows areas of greatest abundance and blue shows the least.

Detailed Talc-Tremolite Map



Ground Data Teams

Long Term Directions



Summary

- ***Strategy and approach to performance assessment reviewed***
  - ***Absolute Radiometric Calibration, Spectral Calibration, Image Quality***
- ***Extensive pre-flight calibration provided solid foundation for on-orbit assessment***
- ***On-Orbit analysis confirms pre-flight characterization***
- ***Instrument continues to perform extremely well***